

THE
NEW YORK
ARCADE RAILWAY,

AS PROJECTED,

COMPARED

WITH THE

UNDERGROUND RAILWAYS

OF

LONDON.

REPORT TO THE

Broadway Underground Railway Co.

—BY—

WM. J. McALPINE, Engineer-in-Chief.

1884.



NEW YORK ARCADE RAILWAY. MELVILLE C. SMITH, President.
(View up Broadway, from Pine Street.)

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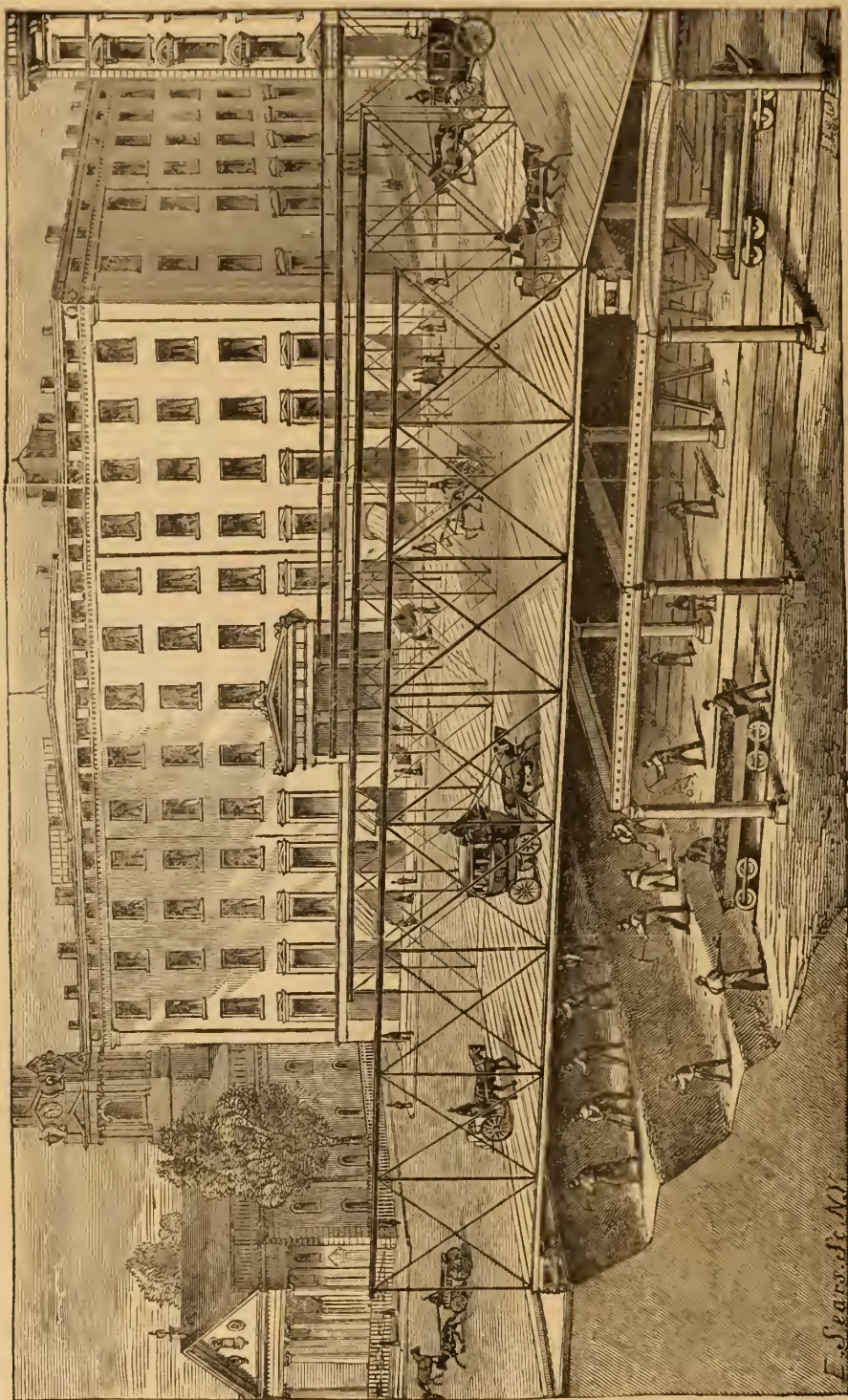
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PLAN FOR BUILDING THE ARCADE WITHOUT INTERRUPTION TO TRAVEL.

PLAN FOR BUILDING THE ARCADE,

WITHOUT INTERRUPTION TO TRAVEL.



The work on the Arcade will be commenced by placing along the line of the roadway two iron bridges, of from 500 to 1000 feet in length, and each 18 feet wide in the clear, and along the line of sidewalks corresponding bridges, each about 12 feet wide. These bridges to be supported at intermediate points.

The floor of these bridges will be elevated four feet above the grade of the street, and the difference in elevation overcome by a gentle ascent at each end.

The skeleton frame trusses will form but slight obstruction to the view, and permit pedestrians to cross the streets at all places.

The panels are made separate and bolted together, and may be taken down from one end and added to the other with facility.

Convenient access to and from the bridges will be provided, and the work on the railway will be carried on under the bridge, without using the street, either in the removal of excavations or in bringing materials to construct the road; the completed Arcade being ample for these uses, and affording abundant store-room for all the purposes of construction.

The street in front of an ordinary building would be occupied by the bridges and workmen about one month, and during this time (by the plan proposed) the occupants of the building would suffer but little inconvenience, and the street travel little, if any, obstruction.

HON. MELVILLE C. SMITH,

President of the Broadway Underground Railway.

Sir :

The annexed report is a statement of my recent examination of the London Underground Railways, and a comparison between them and the projected Arcade Railway of New York.

There are also appended diagrams and sketches of those works, and many maps, profiles, sections, working drawings, together with printed reports and statistics, including many you procured while on your tour of inspection with Directors Hon. William Windom and Jerome Fassler, of the Underground Railways and Structures in the cities of London and Paris.

I have also to acknowledge the valuable information obtained and work accomplished by Engineer Frederick N. Blanc, whom you left in London, in the employ of your Company.

These papers, &c., submitted, with others which I am to receive from Europe, will be of great value when the construction of the New York Arcade Railway is commenced.

I have also in preparation a report and discussion of the application of several kinds of motive power to the Railway, which will be hereafter submitted to you.

Respectfully,

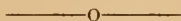
WM. J. McALPINE,

Engineer in Chief.

New York, January, 1884.

COMPARISON

OF THE PROPOSED NEW YORK ARCADE RAILWAY, WITH THE UNDERGROUND RAILWAYS OF LONDON.



THE results of the construction and operation of the Underground Railways of London, have demonstrated not only the feasibility of the New York Arcade Railway, but have also shown that the apprehensions sometimes expressed, that adjacent private property would be injured and the traffic of the street partly inconvenienced, are wholly without foundation in fact.

The large and steady increase in the traffic and net revenues of these London Railways, gives assurance that the one projected for New York will prove a successful enterprise.

The correctness of these statements will be shown by the following comparisons between the "Inner Circle" of the two London Railways and the New York Arcade.

The "Inner Circle" comprises twelve miles of circumference, enclosing about seven square miles, mainly of the heart of London.

First:—This London line has been built chiefly under or through the most costly property in the world, and less than one-third of its length passes under the streets (Euston, Marylebone and Embankment) thus adding immeasurably to the difficulties and obstructions to be met and overcome, and as a consequence enhancing greatly the dangers and cost of construction.

The New York Railway will pass entirely under the streets, and in no instance under or near any valuable buildings or property.

Second:—Four miles of the London Railways have been built with the grades from thirteen to twenty feet below tide water level.

The New York Railway will have less than a third of a mile of its grade below tide level, and at its deepest place but five feet below low tide.

Third:—The excavations for the London Railways have been made chiefly in stiff clay, and in many places among the walls and debris of the old Roman works, in others they had to be made by small divided tunnels and strong wooden protections, involving expensive work.

The excavations for the New York Railway will be chiefly sand and gravel, though some ten per cent. of the distance will be in rock, which must be quarried, but as a whole, the cost of the excavation will be considerably less.

Fourth:—The crossing streets of the London Railway are crooked and very narrow, and portions of them have been occupied during the construction of the underground works.

The New York Railway will be built beneath a series of moveable bridges with tramways underneath, on which all of the materials will be conveyed, so that no portion of either the main or cross streets will be used or interrupted.

Fifth:—The construction of the London Railways required radical changes in the lines and grades of the sewers (some of immense size), water and gas pipes, many of which were very old and decayed.

There are no continuous sewers in lower Broadway, New York. The few existing are generally of small size, and the changes in their grades and outlet can be easily made. Continuous vaults will be made on each side of the Railway, or under the road bed, in which will be placed complete systems of sewer, water, gas, telegraph wires, heating and other pipes, where they will all be open for inspection, repairs and replacements, without interrupting the street or railway traffic, and do away forever with the present almost constant interruption of the trade and travel.

Sixth:—The ventilation of the London Railway tunnels, with 20 stations of 300 to 500 feet in length, open more or less to the air above, is generally considered good, though the heavy, humid atmosphere and very dense fogs of London, taken in connection with the consumption of coal, and imperfect condensation of steam of the locomotives used, render it more difficult to secure perfect ventilation.

There is one continuous tunnel of $2\frac{1}{4}$ miles from Kings Cross to Edgware Road, where small narrow openings of 3 by 15 feet extend from the tunnel roof to the street surface, and even here the ventilation is made moderately good.

On the New York Arcade Railway there will be five times the number of stations with openings to the air in a corresponding distance, and the openings will be larger than on the London Railway. This, with a continuous opening of about 6 feet on each side of the Arcade, adjacent to the buildings, the absence of fuel combustion in the engines, and the use of steam condensing locomotives, would, beyond a question, render the atmosphere of the Arcade pure, and the ventilation perfect.

Seventh:—There are 530 trains dispatched daily between 5 A. M. and midnight on the London Railway, of which half are sent at intervals of three minutes, and the other trains usually at four and seven minutes.

By means of the "Lock system," trains on other Railroads in London are dispatched every two minutes. The maximum capacity both ways of the London underground double track railway at two minute intervals for twenty-four hours (for passengers and freight) would be 1440 trains daily.

The New York four track railway, with trains every two minutes, would have a maximum capacity of twice that of the London, which, with its more powerful engines and larger trains, would be equal to the

movement of about five hundred thousand passengers and about an equal number of tons of freight each day.

Eighth:—The schedule time of trains on the London Railway, between Aldgate and the Mansion House (twelve miles) is 63 minutes. The speed varies from 8 to 14 miles an hour, including 22 stops, or, while in motion, from 16 to 20 miles an hour.

The way trains on the New York Railway will be run at ten miles an hour, including about ten stops on each mile. The express trains will be run at the rate of thirty miles an hour, including one stop in each mile.

That is, from the foot of Whitehall street to 30th in 6 minutes, or to Central Park in 10 minutes, or to 100th street in 15 minutes, or to 130th street in 17 minutes, or to High Bridge in 22 minutes, or to the North line of the city in 34 minutes.

Ninth:—The London Railways have been tunneled under many high, large and valuable buildings* and under every variety of structure met with in a great city, including a monument of 168 tons. In many places the walls of the tunnels have been founded from ten to twenty feet lower than the foundations of adjacent buildings, and in some places the foundations of these adjacent buildings, many being very old and of decayed material, have been underpinned from six to sixteen feet in depth. But in all these cases, through the admirable plans of the English Engineers, the Underground Railway has been constructed with complete success, and without causing any injury whatever to the buildings.

There is no part of the New York Railway where such difficult work will be required. The excavations for the Arcade Railway will not extend to within eighteen feet of the face line of any of the buildings, and the excavations for the vaults (constructed for the city's use), where they are deeper than the foundations of any of the buildings, will be made upon the same successful plans which were used in London.

The underpinning of such of the buildings as will be found necessary, will be of less extent and far less difficult, and can be made without the slightest injury to them.

Tenth:—The grades of the London Railway are very undulating, and in some places very steep. On the Metropolitan portion of the "Inner Circle" they are generally one in one hundred, and in one place one in seventy. The grades of the District portion are flatter and less undulating. On the "Widening lines," to connect with the country railways, there are grades of one in thirty-nine, in forty, in forty-six, and one in fifty feet.

Two-thirds of the length of the Railway is one curve of 660, 1,000 and 2,000 feet radii.

The New York Railway will be almost a continuous straight line, with very light grades. At Canal Street, and that only for a half a mile there will be a grade of 1 foot in 82.

* NOTE.—At St. James station, the highest building in London, viz, 14 stories, is within 20 feet of the Railway.

In 1877, the Metropolitan had expended on its line from Aldgate to South Kensington ($7 \frac{9}{10}$ miles of the main track and $2 \frac{9}{10}$ miles of widening, etc., for this portion of the "Inner Circle,") as follows:

For land and indemnities, - - -	\$18,672,540
For excavations and works, - - -	13,360,899
For general expenses, - - - -	2,278,161
For rolling stock, - - - - -	1,329,290

Making a total of \$35,640,890

Including some unpaid accounts, the cost per mile for this $10 \frac{4}{10}$ miles was \$3,339,645.

During the year 1882 the passengers carried were as follows:

First class Metropolitan, 3,485,910	District, 3,313,752
Second " " 8,131,499	" 6,411,686
Third " " 50,188,109	" 22,182,313
Season est'd " 3,300,000	" 2,400,000
Total passengers, 65,105,518	34,307,751
Together - - - 99,413,269	
Mileage of passenger trains 1,399,926	1,098,736
	METRO. DIST.
Total Receipts - - - \$3,193,735	\$1,873,200
Total Expense - - - 1,358,320	861,565
Total per cent. net expenses - 43	- 46

New York City is very differently situated. The business is chiefly confined to the lower end of the island, and there is but one natural free outlet, which is directly Northward. This route is confined by deep water channels, the passage of which is obstructed by fogs, ice and all of the discomforts, delays and dangers of ferry voyages.

The immense business which is concentrated at the lower, narrow end of the city has shown that the streets in that section are too few for the business and the houses. The property is too valuable to permit the opening of new streets or even the enlargement of those existing.

The number of drays and carts alone, daily passing in Broadway, are more than seven thousand. These with vehicles entering from the side streets frequently so gorge and obstruct this great thoroughfare that travel is for hours entirely suspended.

The immense loss and annoyance through this obstruction is greatly aggravated by the street being constantly torn up in connection with sewer, gas, water, steam heating and other pipes.

The surface and elevated railways offer inconvenient and insufficient accommodation to passengers between that portion of the city devoted to business and that occupied by residences, yet they are crowded to their utmost capacity, because nothing better is afforded.

Eleventh :—The locomotives of the London Railways are all of one type of 42 tons weight and 5 feet 6 inch drivers. The trains usually consist of from three to six carriages, with capacity for conveying 30 passengers each.

The express locomotives on the New York Railway will have power to haul twelve or fifteen carriages, which will seat sixty passengers in each.

Twelfth :—I examined a great many places on the line of the “Inner Circle,” to ascertain whether the trains passing through the tunnels of the London Underground Railways produced any vibration or jar of the buildings above and adjacent to the Railway, but nowhere could detect the slightest motion. I was informed that careful tests with very delicate instruments were made some years ago, and that no motion or jar as great as that produced by an ordinary vehicle passing on the street was anywhere found. The Engineers state, that in twenty years they have never been called upon to pay a guinea for damages to overhead or contiguous buildings or property.

In some places peat or tan bark was put under the sleepers, but these precautions were subsequently found to be unnecessary.

On the New York Arcade the way tracks will be 18 feet distant from the face of the buildings, which space will be vaulted so that the trains in motion cannot possibly produce vibration or jar to the buildings. The tracks of the express trains will be 11 feet still further removed from the buildings.

Thirteenth :—The numerous Railways of London radiate in every direction from the business portions to the suburban residences, extending to a complete circuit of more than thirty miles in diameter, and distribute this kind of travel over more than twenty different lines, and yet every one of them has an amount of business which pays a fair return for even the enormous cost of these radiating railways, and this is particularly the case with the very costly underground railways.

The London Metropolitan Railway, in January, 1863, had opened three and one-third miles for travel, and in 1868 about as much more. The Metropolitan District Railway opened two and a half miles in 1868, and one and a half miles in 1870, and has now, in connection with other Companies, two miles in progress.

The Metropolitan, with its branches running out from the city, is twenty-two miles in length, on which there has been expended about fifty-five millions of dollars.

The Metropolitan District with its branches is thirteen miles in length, on which there has been expended about thirty-five millions of dollars.

Since the opening of the Elevated Railways the increase of travel has been more than all the passengers they carry, showing that the travel in this direction will increase up to the extent of the accommodation which is offered.

The Arcade offers in all respect the most effectual remedy and relief the ingenuity of man can contrive. It duplicates the street; it offers the most complete accommodation for way and through travel; it furnishes cheap and rapid transportation for freight and express; and by thus removing all obstructive vehicles from the upper street, systematizing the travel, and by the application of a motive power vastly more effective than can be used on the surface street, it would treble the capacity of Broadway in all the essential elements which make a street useful, and adjacent property valuable.

Our visit was fortunately timed, as we found the Engineers engaged in constructing one of the most intricate and difficult portions of the Railway, viz.: upon the two miles of the extension eastward from the Mansion House, through a net work of narrow and crooked streets, along which were standing every variety of buildings, from the heaviest and most costly to the oldest and most decayed.

Many of these, especially the latter, were torn down, either for the extension of the stations or for the purpose of providing additional breathing places, and others were maintained by tunneling under them for the passage of the Railway.

The works on this line embraced all of the varieties of construction which had been adopted elsewhere on the Railway, and we found them in every stage of progress, from that of placing the temporary roadways and works, temporarily securing the water, gas and sewage pipes, and the permanent works therefor; the wooden protections and small tunnel excavations for underpinning and supporting the houses, and for excavating and laying up the side walls, also of the top arching and placement of the iron girders, and of the method of excavating and removing the materials.*

At Victoria street the Railway was carried under a very large and heavy brewery. In this case the side walls and arch covering were increased in thickness, and twelve massive wrought iron girders were stretched across above the arch to take the weight of the building and of the large weighty vats.

Near the same place the foundation of the Railway had to be placed at 15 feet below the level of the base walls of some high buildings, and in another case the Railway was carried diagonally under another set of heavy buildings.

At St. James station there is a house of fourteen stories high—the highest dwelling in London. The Railway excavations were made within 20 feet of its face and 15 feet below the level of its base walls.

At Victoria Station the Railway was carried under the largest sewer in London, having a cross section of 151 square feet.

The level of the invert of this sewer is 8 feet below high-tide in the Thames, and the rail level of the Railway had to be depressed to 21 feet 9 inches below, and the excavations at this place had to be extended to 28 feet below high or 15 feet below low water tide level.

* NOTE.—There has been taken from the deep excavations on this, the oldest part of London, a great many rude Roman implements and pieces of pottery of an earlier date.

At Sloane Square Station two cast-iron sewers are carried over the Railway; one of them is 9 feet diameter and crosses the Railway diagonally. It is supported on each side by a wrought iron girder of 73 feet length, $6\frac{1}{2}$ feet depth, and flanges of 2 feet width.

At Blackfriar Station a very complicated construction was required. The grade of the Railway had to be placed at 10 feet below high tide to pass under the north approach of Blackfriar's Bridge. Two sub-ways had to be carried over the Railway and the low level sewer under it, and the outlet for the gas company, the Fleet Street sewer and its storm-water conduit overflow had to be provided for. All of these lines met nearly at one place and crossed the Railway very obliquely. Those passing above the Railway were sustained by girders, some of which were 75 feet long.

At Pembroke square the Railway was carried very obliquely under eight new and valuable houses. The level of the rails is 20 feet below the street and 11 feet below the foundations of the houses.

The Railway was carried under the London Hospital in nearly the same manner. This is a massive stone building of four stories.

The underpinning was completed while I was in London, and I carefully examined the building, but did not find that any injury had been done, not even the cracking of the plastered walls.

The Railway passes within 10 feet of a row of large cut stone buildings in Cannon street, and as excavations therefor were dug to a level 15 feet below their foundations, with the precautions taken no injury has been done to them. It also passes flush with the tower of St. Mary's (White Chapel) Church in Aldgate street, and the Railway excavations were made $8\frac{1}{2}$ feet below the level of its foundation. No injury whatever has been done to the tower or church.

This portion of the Railway has been carried under and in front of many other buildings, and in no instance have they been injured.

In the middle of King William Street is a monument of William IV. which, with its base, weighs 168 tons, and the Railway is tunneled directly under this statue.

The Railway passes in front of the South Eastern Railway Station and Hotel. When we examined this work we found that the whole of this area had been temporarily bridged over, and the underground works were in progress.

Large granite blocks of 5 feet square had been laid on concrete bases; on these were to be placed iron columns surmounted by iron girders and jack arches, which were to support the carriage travel over the area in front of the station, and the space below was to be used for the Underground Railway Station.

The brick sewers were temporarily sustained by cradles and props. A gas-main of 24 inches diameter was suspended from the wooden bridge, and two 12 inch and several small water-pipes were also suspended or propped up from below. The sidewalks of the Railway in one place were in process of erection; in another place the roof arching; in another the roof girders; in another the inverted arches and track work, so that in one short distance could be seen the actual construction of almost all the varieties of work required in the building of any portion of the Railway.

The underground depot at Smithfield Market, is 625 by 240 feet square, with 24½ feet head-room. The vaults at the sides are in bays of 25 by 15 feet, covered by arches of masonry.

The remainder of the upper market area is supported by iron columns and girders. Some of the cast iron columns are of 18 inches diameter, and carry 400 tons weight. Some of the girders are 4½ feet deep, boxed with flanges 2½ feet wide.

Resting on brick and concrete bases are 180 wrought iron columns, made generally of channel bars of 12 by 3½ by 1½ inches, and plates of 15 by 1 inch. Some of them are double.

The stations are roofed with iron arched ribs of 87 feet span and 29 feet rise.

I examined the locomotives and machinery of the Kings Cross and Hallowell Railway, where compressed air is used for the motive power. There is no doubt but that this motive power has or can be successfully applied with advantage upon tunnel railways, though perhaps at a greater cost than that of the usual locomotive.

I examined the fireless locomotives in use upon the Rueil and Marly-le-Roy Railway, near Paris. These engines are run 10 miles, starting with steam at a pressure of fifteen atmospheres, and completing their trips with the steam at two atmospheres pressure.

These engines draw a train of 44 tons weight over a street Railway with much sharp curvature and high grades, at an average speed of 10 to 15 miles an hour.* The steam is exhausted into the open air, but on the Mekarski Railway in Lille it is condensed as on the locomotives of the London railways.

I have examined several electric motors, and have received information in regard to their use in Europe and experimentally in this country.

I have examined the cable system in use here, and have accounts of its application elsewhere. For the way trains of the Arcade at moderate speed this system may be applicable. The experiments so far do not show that it can be applied to the fast express trains, although I have devised a plan by which I hope to make it applicable to any desired speed.

I am to receive, in a few weeks, the monthly statements of the business done, and the detailed expenses thereof, upon these Continental Railways, and will then submit a statement of the comparative value of this and of the other proposed systems of motive power, as applicable to the New York Arcade Railway.

The decision in regard to the motive power for the Arcade is not necessary at the present time, and it may perhaps be sufficient now to say, that fireless locomotives, with condensers, can be run with nearly as much economy and as complete certainty as the engines of the London Railway, and it is altogether probable that the electric motor will be perfected, if the cable system is not, so as to be applicable to the Arcade Railway.

* NOTE.—On an extension of this Railway south of Marley, the same Engines draw lighter trains up a grade of 1 foot in 17 with sharp curvatures.

I shall submit, soon, a more extended report, in which many additional facts and details will be given ; those embraced herein, however, cover in a practical way all the obstacles and objections, and those of a far more difficult character than any that will be encountered in the construction of the New York Railway.

WM. J. McALPINE,

Engineer in Chief.

New York, January, 1884.

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